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Evaluations of Differences in Sea Surface Temperatures Between 1987 and 1988 for Use in Study of Sea Turtle Strandings Along the Southeast U.S. Coast

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ABSTRACT

During the period from October through December 1988, numerous sea turtles were observed stranded dead along the beaches of southern Georgia and northeastern Florida. Among the stranded animals were 78 Kemp's ridley turtles, the most critically depleted of all sea turtles (Thompson 1988). While it is not unusual for large numbers of turtles to strand at this time of year, it is unusual for large numbers of Kemp's ridley turtles to strand in this area, or any area.[1] The Southeast Fisheries Center (SEFC) initiated an investigation into the possible causes of the strandings. As part of this investigation the Marine Climatology Investigation (MCI) of the Northeast Fisheries Center (NEFC) was asked to evaluate sea surface temperatures (SST) along the eastern coastline to determine if SST variations might have influenced migration patterns. Since no similar event occurred in 1987, the 1987 data were used as a baseline for evaluating SST in 1988. Satellite data from NOAA-9 and NOAA-11 were used to calculate SST differences for the two years.

The results show no significant trend or specific thermal event which directly affected the turtle strandings. Several minor features are noted, however, these do not appear to be related to the strandings. Data from NOAA weather buoys confirm these findings. Further study would be valuable to determine the variability of SST in relation to turtle migration patterns.

Introduction

In October 1988, large numbers of turtles, including the endangered Kemp's ridley turtles were reported washing up dead on the beaches of southern Georgia and northeastern Florida. The total number of dead turtles that washed ashore by the end of December 1988 had reached 78 Kemp's and 201 loggerhead and leatherback turtles. The Southeast Fisheries Center (SEFC) initiated an investigation of this mortality. The possible causes examined were: shrimping or other fishery activities; disease or toxins; dredging activities at the Georgia-Florida border in October and November 1988 and; environmental factors. It appears that this high mortality rate reflected an unusual aggregation of Kemp's ridleys in this area during the fall of 1988. In previous years, mass strandings of ridleys were reported in the fall and early winter off the New England coast (Schroeder 1987; Schroeder and Warner 1988). These strandings off New England probably resulted from turtles that lingered in northern waters and died when temperatures dropped below the animals' physiological minimum. No such "cold-stunning" event occurred in 1988, for the first time since such strandings have been recorded (beginning in 1980). Thus, it was hypothesized that the turtles may have shifted their migration in 1988, leaving northern waters earlier than in previous years, possibly as a result of an earlier thermal cue (Thompson, Memo 1989).

As part of the investigation, the SEFC requested that the Marine Climatology Investigation (MCI) of the NEFC evaluate sea surface temperature (SST) along the U.S. east coast. The purpose of our study was to look for evidence of any trend in SST which might act as a thermal cue for migration or otherwise influence the turtles' behavior. Since no similar event occurred in 1987, our evaluation focused on a comparison of SST between 1988 and 1987. This report details methods, results and analysis of our study.

[1] N.B. Thompson, NOAA/NMFS Southeast Fisheries Center, Miami, FL. Personal communication.

Methods

Two to three satellite infrared images per day from the Advanced Very High Resolution Radiometer (AVHRR) aboard NOAA-9 and NOAA-11 polar orbiting satellites were used for this study. These atmospherically corrected data have a spatial resolution of 4 km (subsampled from the original 1 km data), a temperature accuracy of about 0.75°C (Cornillon and Stramma 1985) and a temperature resolution of about 0.125°C (Schwalb 1978). A study period of October 1988 through January 1989 was chosen. The geographic area of coverage was along the east coast from Cape Cod to southern Florida. The study focused on the coastal waters since at least one study showed that the turtles ranged in the coastal waters inshore of the Gulf Stream (Henwood and Ogren 1987). Also, the northern waters, especially off Cape Cod, MA, were examined closely in October and November to determine if thermal migratory cues could be identified.

The digital images were remapped to display the study area. The navigation for each image was checked and corrected as necessary. Three-day composite images then were produced to reduce the area of cloud contamination. The compositing process saves the warmest temperature value from all the input images on a pixel by pixel basis (each pixel represents approximately 4 km by 4 km). By dropping the cold values, this process filters out some of the clouds which appear on the images as very cold temperatures.

The three-day composite images were examined for cloud cover. Several images were removed from the data set because of persistent cloud cover. Temperature differences were then calculated between each three-day composite in 1988 and the corresponding composite image in 1987. The differences were contoured and three charts were produced for each three-day period. One chart displayed the entire study area at a small scale (see Appendix A). The other charts showed the northern (Cape Cod to 33°N) and Southern (34°N to Florida) areas at a larger scale.

Several months after generating the charts and conducting the analyses, MCI was notified of a problem with the atmospheric correction algorithm applied in processing the raw infrared data. This problem resulted in possible errors in the actual temperatures calculated from NOAA-11 data. Since both satellites were fully operational during the last two weeks of October there were overlapping data for that time. In order to estimate the magnitude of any errors in SST calculations, we generated temperature difference charts comparing NOAA-11 data with NOAA-9 data for this period of overlapping coverage. We did find some differences, however the results indicated that there may be some variance in quantitative results but the qualitative conclusions were valid. Temperatures derived from moored NOAA buoys also were plotted and compared to the satellite derived data. The buoy data provided an independent method of confirming the qualitative analysis of the SST.

Results

The charts were examined for significant between-year differences in SST patterns. The evaluation was done by month and further broken down into four general geographic areas: Cape Cod; Long Island to Cape Hatteras; Cape Hatteras to 31°N; and Florida Atlantic Coast. In general, no strong trend or event was evident from the data, although several minor features were noted. The following discussion is based on the month-by-month analysis. The terms warmer and cooler always refer to 1988 SST with respect to 1987 (or SST in January 1989 with respect to January 1988).

In October, temperature differences fluctuated between 1°C cooler and 2°C warmer in the Cape Cod area, with no trends developing. From Long Island to Cape Hatteras, inshore temperatures were consistently 0° to 1°C cooler in 1988. Offshore in the same area the SST was 0°to 2°C warmer in 1988. By mid-October the north wall of the Gulf Stream was farther inshore in 1988 than in 1987, bringing with it warmer waters. This feature persisted during much of the study period. South of Cape Hatteras to 31°N, SST differences varied from 1°C cooler to 1°C warmer all month. Along Florida there was no difference early in the month, and SST was 1° to 3°C warmer in 1988 during the rest of the month.

In November, Cape Cod Bay was 0° to 2°C cooler in 1988 on the first of the month, then 0° to 3°C warmer the rest of the month. The pattern was similar from Long Island to Hatteras. The north wall of the Gulf Stream continued to be located farther north (inshore) in this region in 1988. South of Cape Hatteras to 31°N, SST was generally 0° to 3°C cooler all month. Off Florida, the SST was 0° to 2°C warmer until the last three days of the month, when SST was 0-3°C cooler in 1988.

In Cape Cod Bay and vicinity, SST was 0° to 3°C warmer throughout December. Inshore from Long Island to Cape Hatteras, the SST differences ranged from 2°C cooler to 3°C warmer. Offshore in this region it was generally warmer by 1° to 2°C. The Gulf Stream north wall continued to be farther inshore in 1988, especially along New Jersey to Cape Hatteras. From Cape Hatteras to 31°N temperatures fluctuated throughout much of the month but were 0° to 3°C cooler by the end of the month. Along the Florida coast SST was generally 1° to 3°C cooler in 1988.

Unfortunately, the sea surface in January was obscured by cloud cover for both years during much of the time. Only four temperature difference charts were produced, all prior to 22 January. Therefore, the data reported here do not cover the whole month. In Cape Cod Bay SST was 1° to 2°C warmer in 1989, although not consistently. From Long Island to Cape Hatteras SST was 1° to 2°C warmer except for a small area at the Apex of New York Bight which was cooler during mid-month. From Cape Hatteras to 31°N SST was warmer inshore by 0° to 4°C and cooler offshore by 0° to 1°C. Along the Florida coast SST was 0° to 4°C warmer early and late in the month, with clouds obscuring the data during mid-month.

Discussion

These results do not show any distinct SST anomaly or significant event during the period from October 1988 to January 1989. Although there were temperature differences during this period compared with the same time in 1987-88, the differences were highly variable and fluctuated in space and time. One would expect that both a more persistent difference in temperature and a more consistent pattern in the differences would be required to have a significant impact on turtle migration, since small magnitude or short-term variability of SST might be attributable to normal seasonal fluctuation and local weather conditions.

The satellite-derived data do not give an indication of a cause for the absence of any cold-stunned turtles in Cape Cod Bay in 1988. In past years several cold-stunned turtles have stranded on the beaches in Massachusetts. It is thought that a critical surface temperature (less than 13°C) triggers the migration from the northern waters (Schwartz 1978). Some animals do not start migrating in time however, and become cold-stunned and stranded. In October 1988, the SST in Cape Cod Bay was 13° to 19°C compared to 12° to 19°C in October 1987. During November of both years the SST dropped below the critical 13°C temperature several times. Therefore, variation in SST does not seem to account for the absence of cold-stunned turtles in 1988.

The data indicate that the north wall of the Gulf Stream was persistently farther north in 1988 beginning in mid-October and lasting throughout the study period. This condition created a wedge of warmer water in 1988 which trended northeastward from Cape Hatteras. It is not known whether this condition could affect the migration patterns of the turtles, however it does not appear to be related directly to the turtle strandings in the southeast. Further study of this event in terms of turtle migration patterns is recommended.

Other minor features were noted as well. Cooling of the waters around Nantucket Shoals occurred approximately one week later (24 October) in 1988 than in 1987 (October 16-21). Also, in general, the waters of the Gulf Stream were 0° to 2°C cooler in 1988 than in 1987. These features do not provide an apparent mechanism for the turtle strandings in 1988-1989.

SST data for 1987 and 1988 from the records of three NOAA buoys, Buoys 44008 (40.7°N, 69.8°W), 44012 (38.8°N, 74.6°W) and Ambrose Light (40.5°N, 73.8°W), were plotted (see Appendix B). Long-term averages were also plotted for Buoys 44008 and 44012 (no long-term data were available for Ambrose Light). No significant differences in SST were found between 1988 and 1987 in the Ambrose Light data for the study period. SST from Buoy 44008 was 0° to 1°C warmer in 1988 than in 1987. However, SST in 1987 was approximately 0° to 3°C cooler than the long-term mean, which matched closely the 1988 SST. Therefore; it was concluded that there was no significant difference between 1988 and the long-term means. For Buoy 44012, 1987 and 1988 SSTs were within 1°C of each other during the period from October through December, although both years were 0° to 2°C warmer than the long-term average. The buoy data confirm the results using satellite derived SST data.

In conclusion, SST during the period from October 1988 to January 1989 did not appear to be significantly different than SST during the same period in 1987-1988. The study did not include a comparison of either year with the long-term mean (which has not been computed), therefore no conclusion can be drawn about how 1988 and 1987 differ from "average conditions. " However, it is not likely that SST variation was a factor in the turtle strandings along the Southeast U.S. coast in 1988, because no similar stranding event ocurred in 1987, and 1987 had SST patterns similar to 1988. Further study is necessary to determine the relationship between turtle migration patterns and SST.

Since the sea turtles travel only in the area along the coast (within 50 km) inshore of the Gulf Stream, only this area was analyzed. Fairly consistent SST differences were noted in two areas outside of the study area. First, several warm core rings (WCRs) in 1987 can be identified by the cooler temperatures in 1988 and the elliptical shape of the contours which represent the shape of the rings themselves (see Appendix A, Figure A2 for Oct 4-6 1988 minus 1987: a 1987 WCR was centered at approximiately 38.1°N, 72.2°W). A second area of negative temperature differences was the Gulf Stream, which was 1° to 3°C cooler throughout much of 1988-1989. Apparently, neither of these anomalies were related to the turtle migration patterns.

Acknowledgement

Processing and analysis of satellite data were done using the facilities and archived data of the Oceanographic Remote Sensing Laboratory, University of Rhode Island.

The authors would like to thank Dr. Nancy Thompson for her guidance and assistance during preparation of this document.

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Thompson, Nancy B. January 20 1989. Memorandum to Nancy Foster, NOAA/NMFS Office of Protected Species and Habitat Conservation, Washington, D.C.

Appendix A
Satellite-Derived
Sea Surface Temperature Difference Charts

The following charts depict SST differences for each available three day period from October, 1988 to January, 1989 as compared to the same period from October, 1987 to January, 1988. Solid lines represent positive temperature differences (*i.e.* warmer temperatures in 1988-1989 than in 1987-1988). Cooler temperatures in 1988-1989 (negative differences) are represented by dashed lines and areas of no differences are shown as bold lines.

Only differences of 4°C to -4°C have been contoured. In general, any area with a greater difference than 4°C indicates clouds, especially when surrounded by a strong temperature gradient (where the contours are drawn very close together). Clouds have been identified and labelled whenever possible. In some cases, an area is obscured by scattered clouds in one or both years giving a mottled appearance to the contours.

Figure A1. October 1-3, 1988 minus 1987.

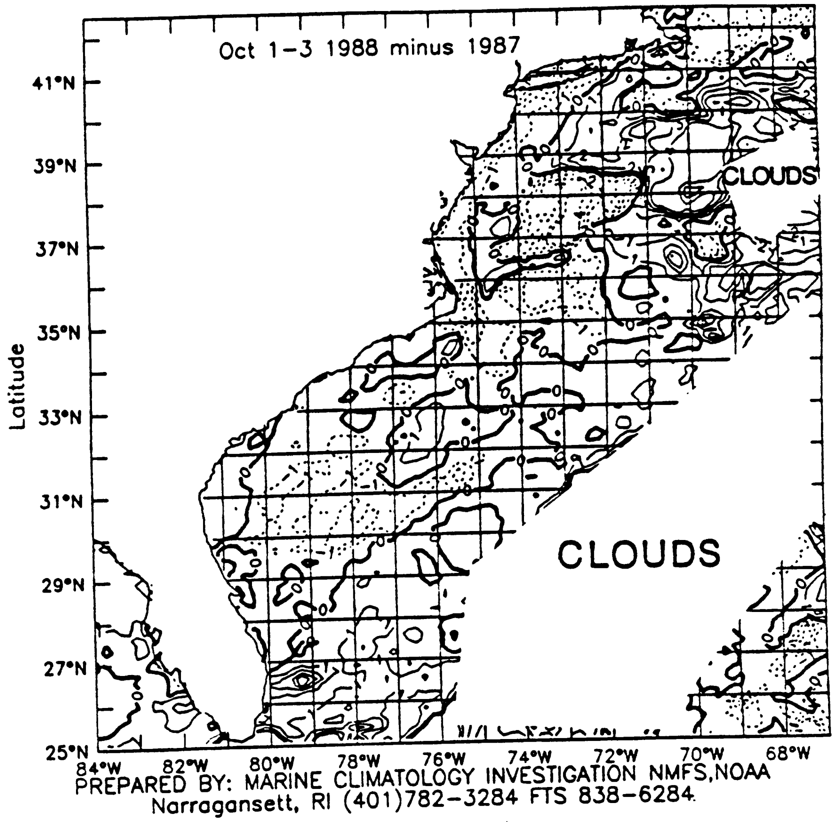


Figure A2. October 4-6, 1988 minus 1987.

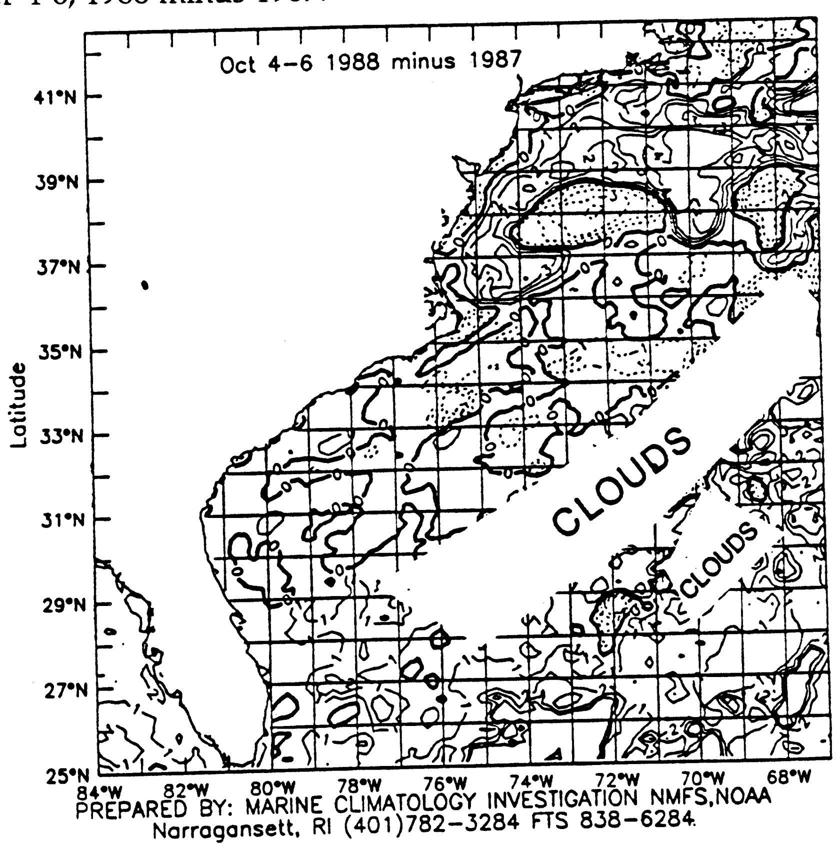


Figure A3. October 7-9, 1988 minus 1987.

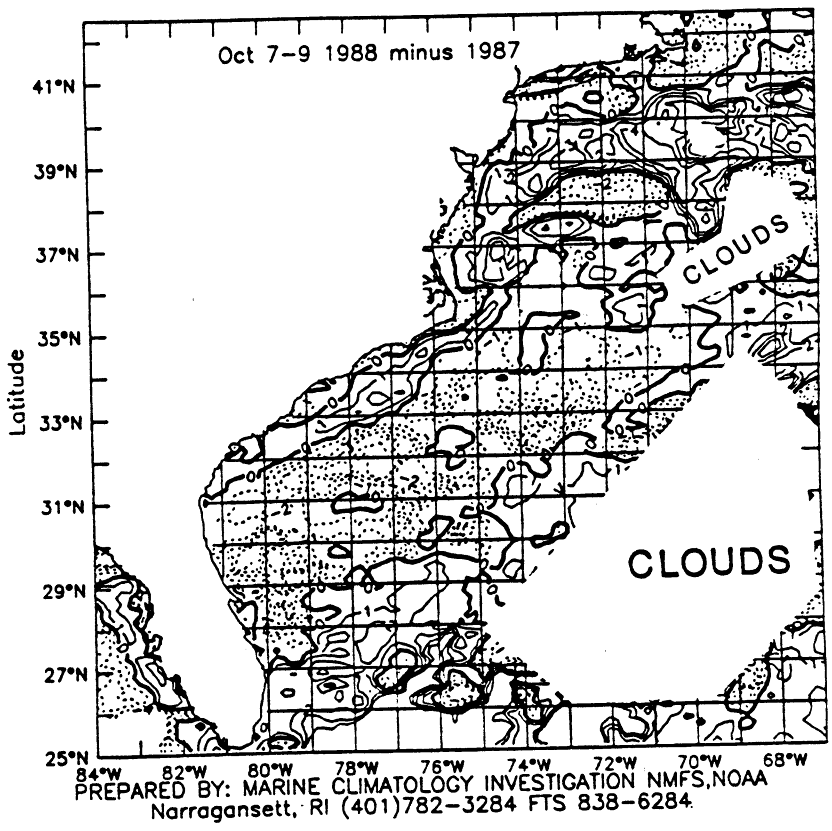


Figure A4. October 10-12, 1988 minus 1987.

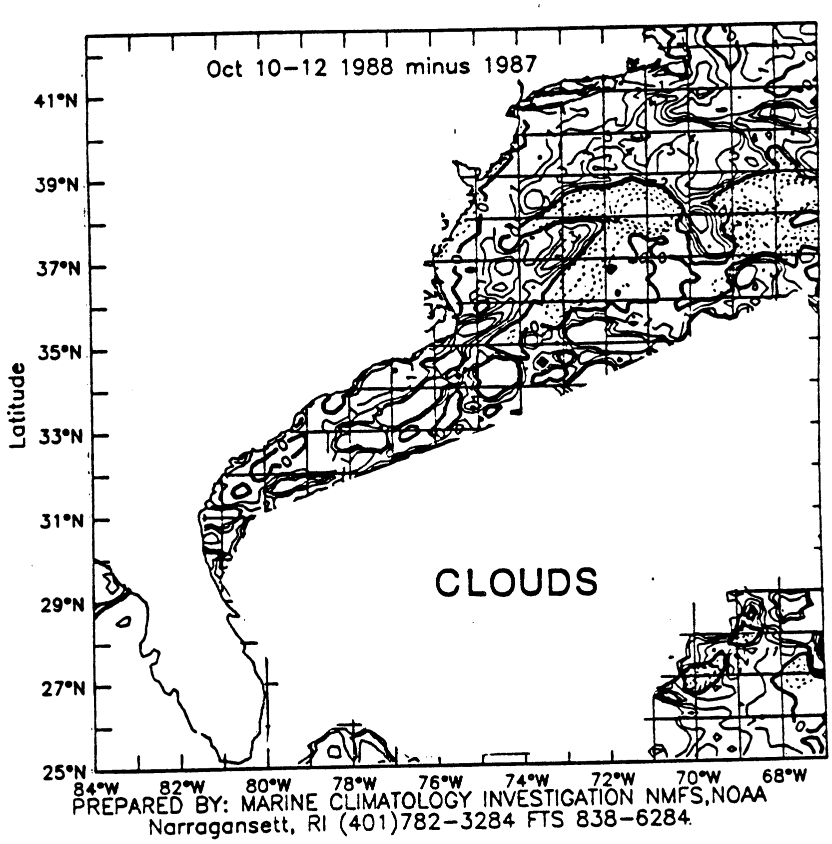


Figure A5. October 16-18, 1988 minus 1987.

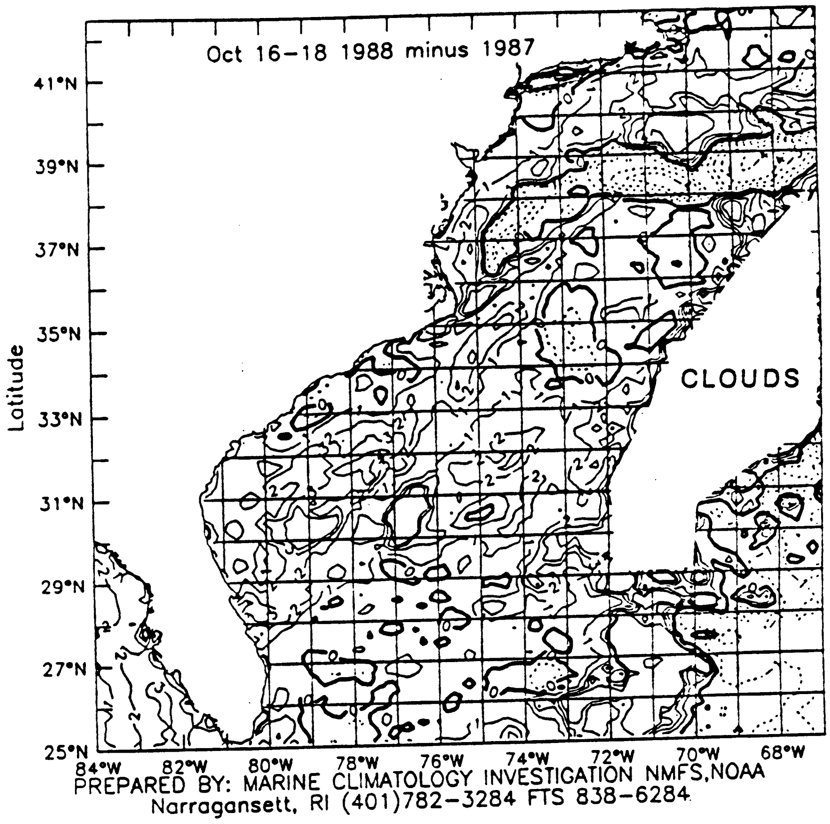


Figure A6. October 19-21, 1988 minus 1987.

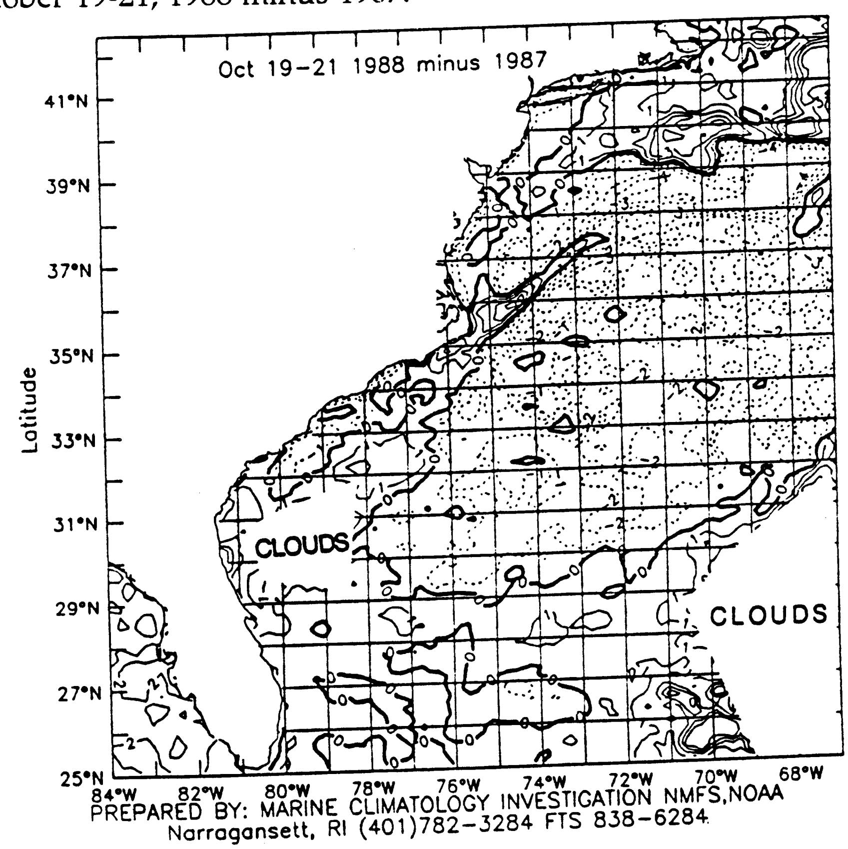


Figure A7. October 22-24, 1988 minus 1987.

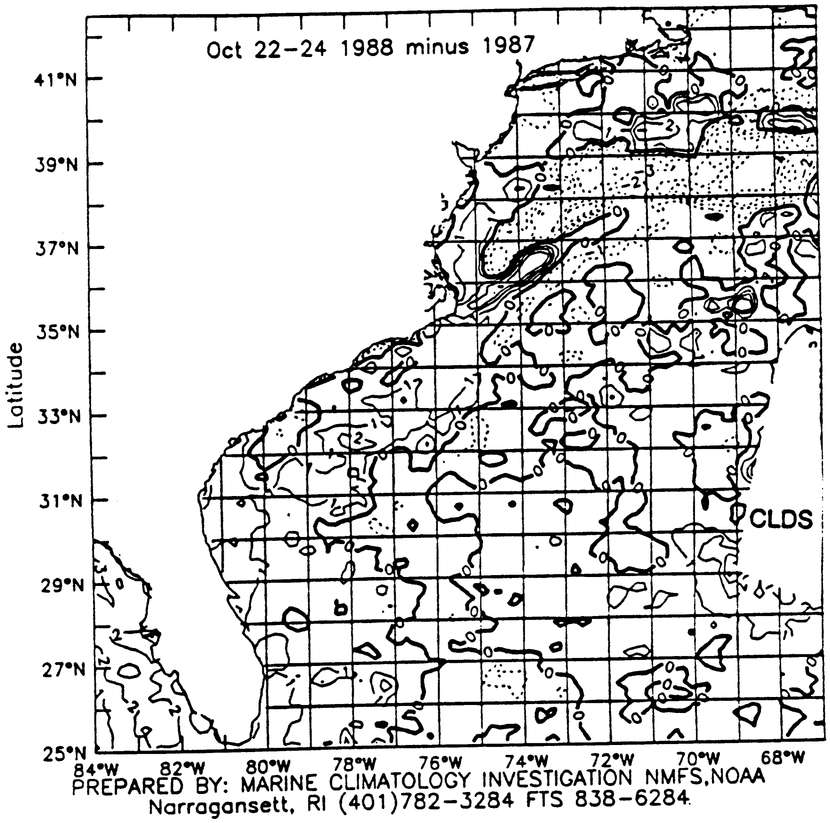


Figure A8. October 25-27, 1988 minus 1987.

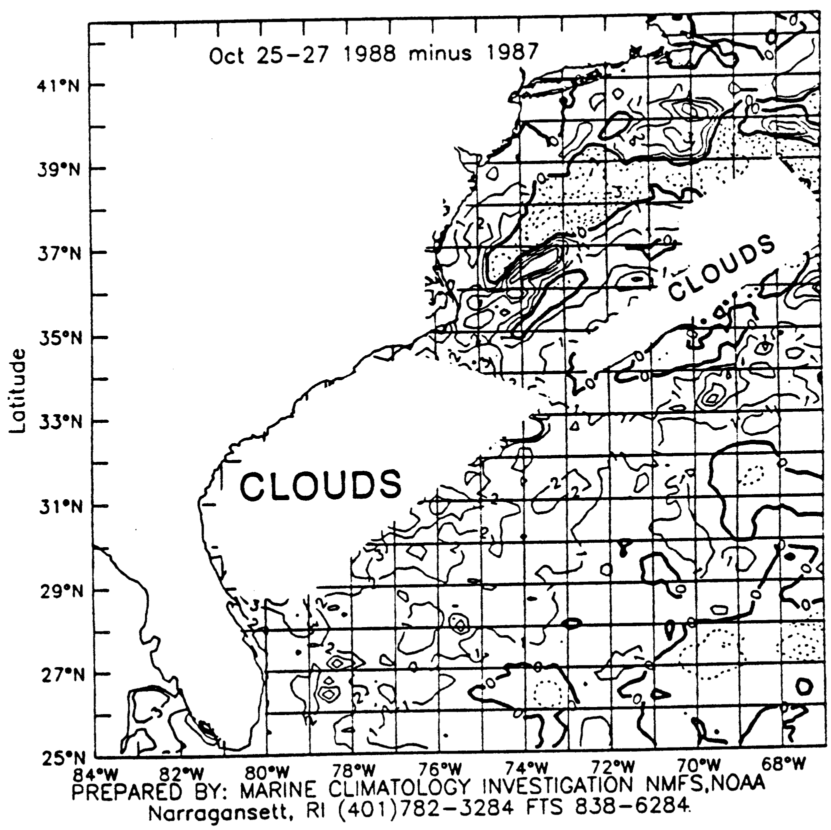


Figure A9. October 28-31, 1988 minus 1987.

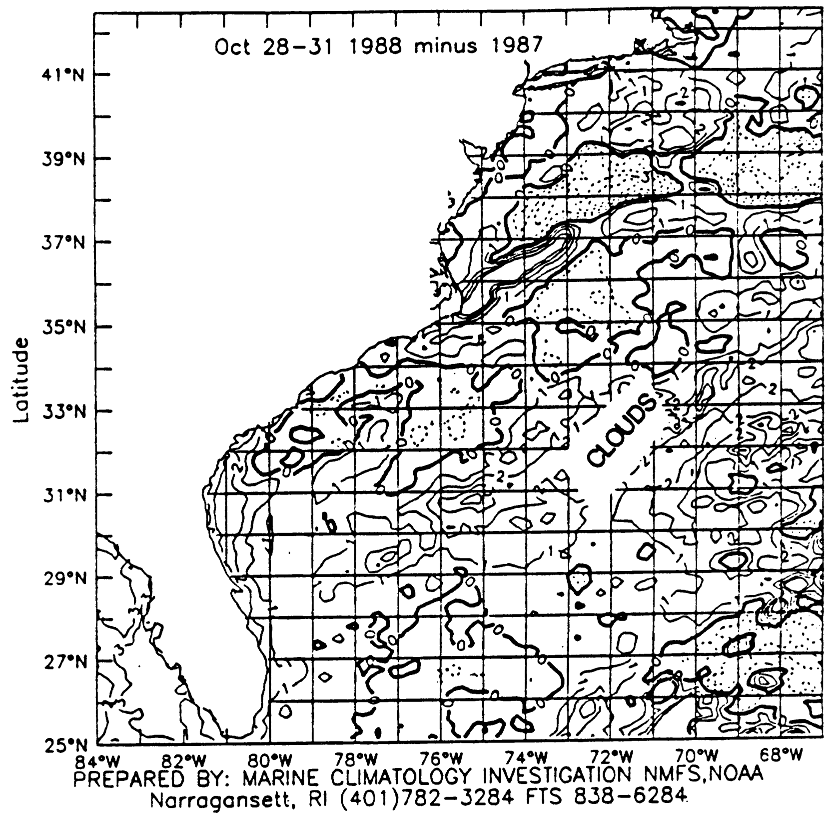


Figure A10. November 1-3, 1988 minus 1987.

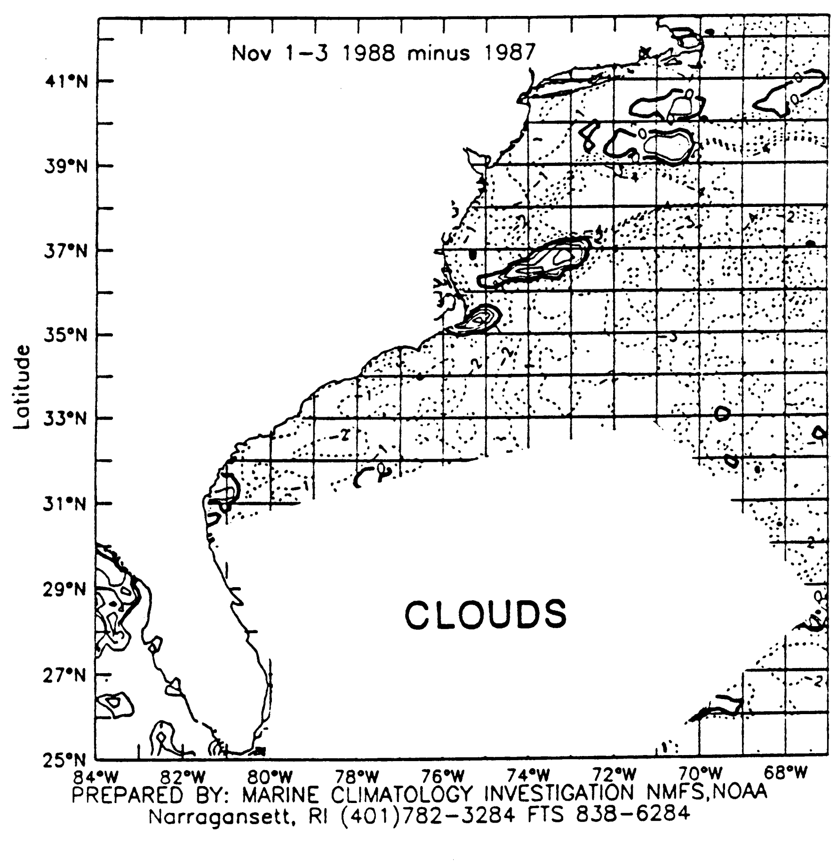


Figure A11. November 4-6, 1988 minus 1987.

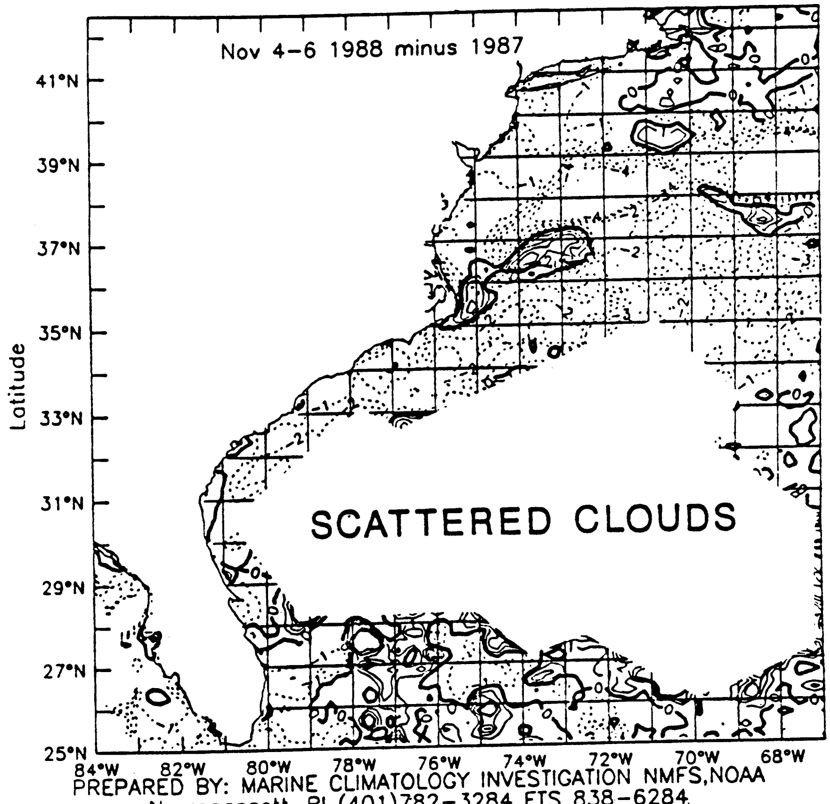


Figure A12. November 7-9, 1988 minus 1987.

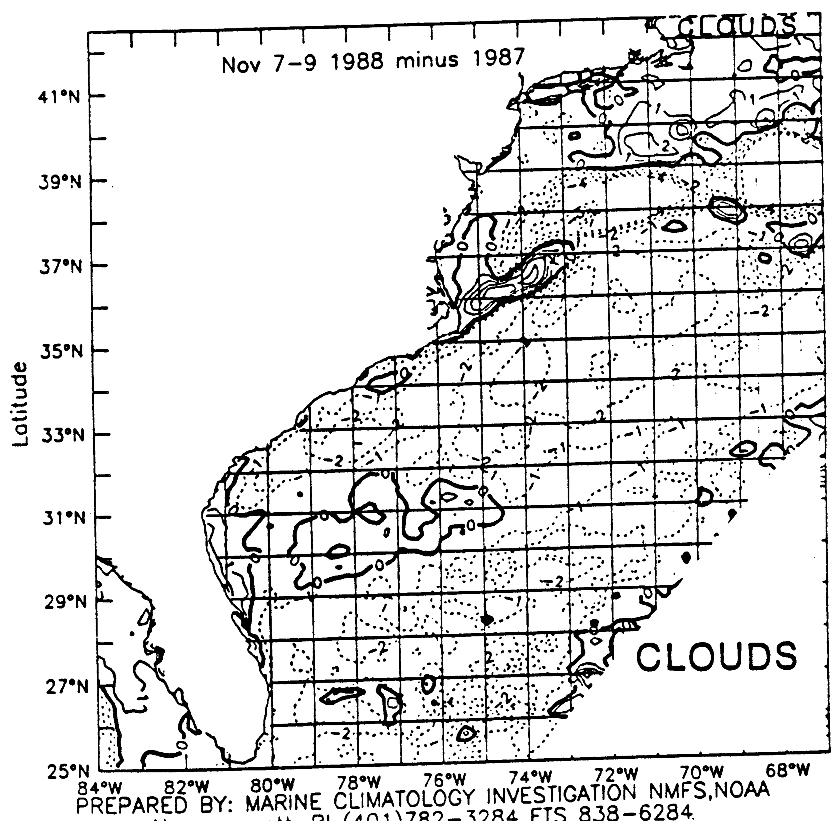
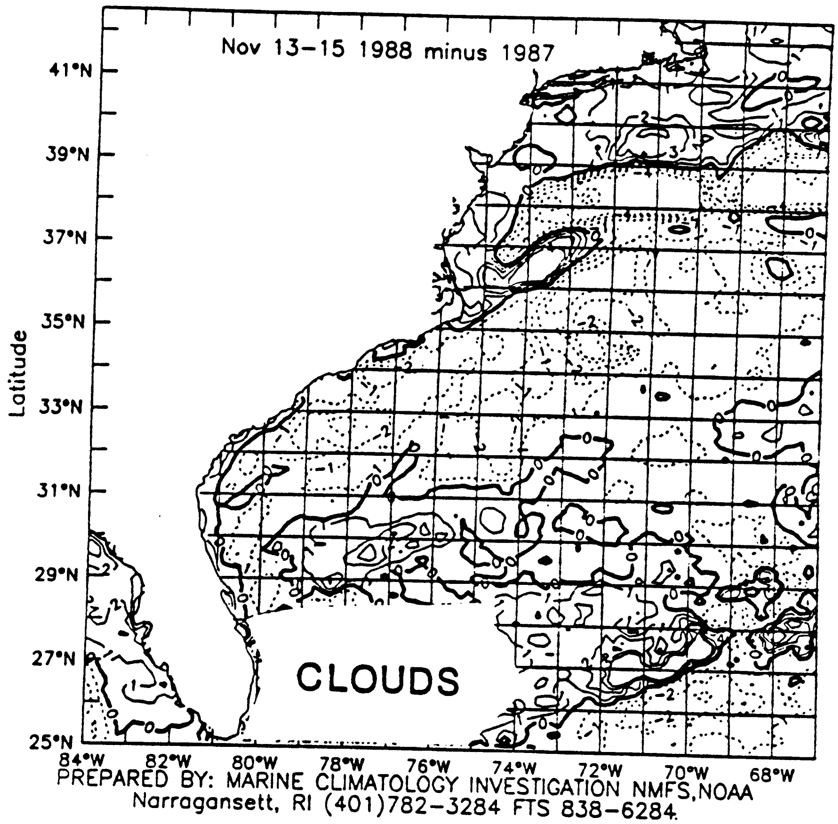


Figure A13. November 13-15, 1988 minus 1987.



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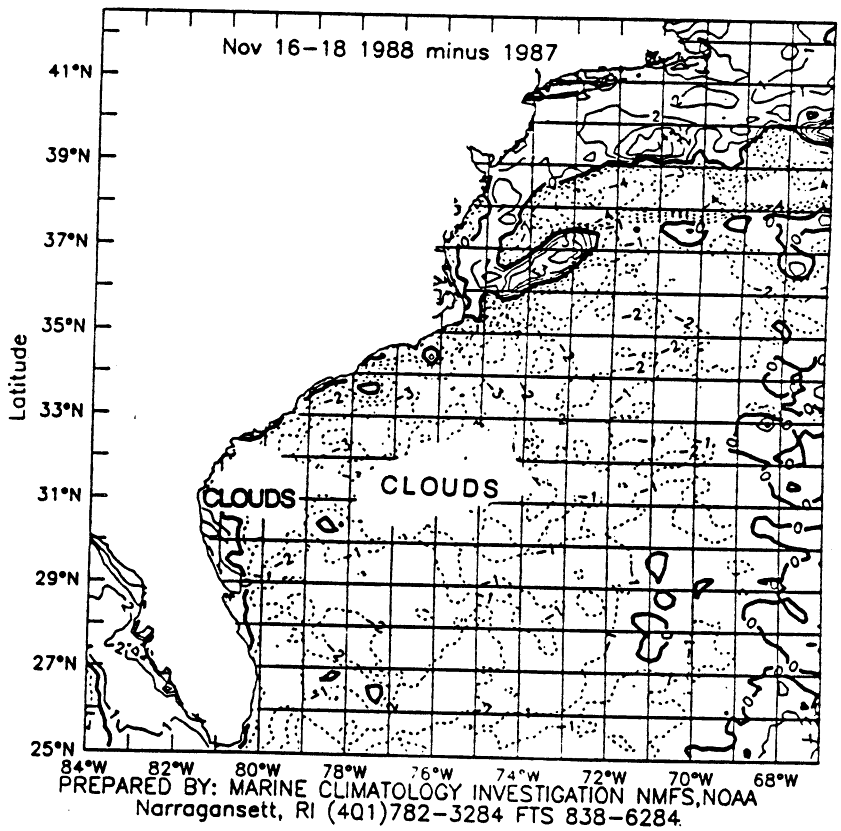

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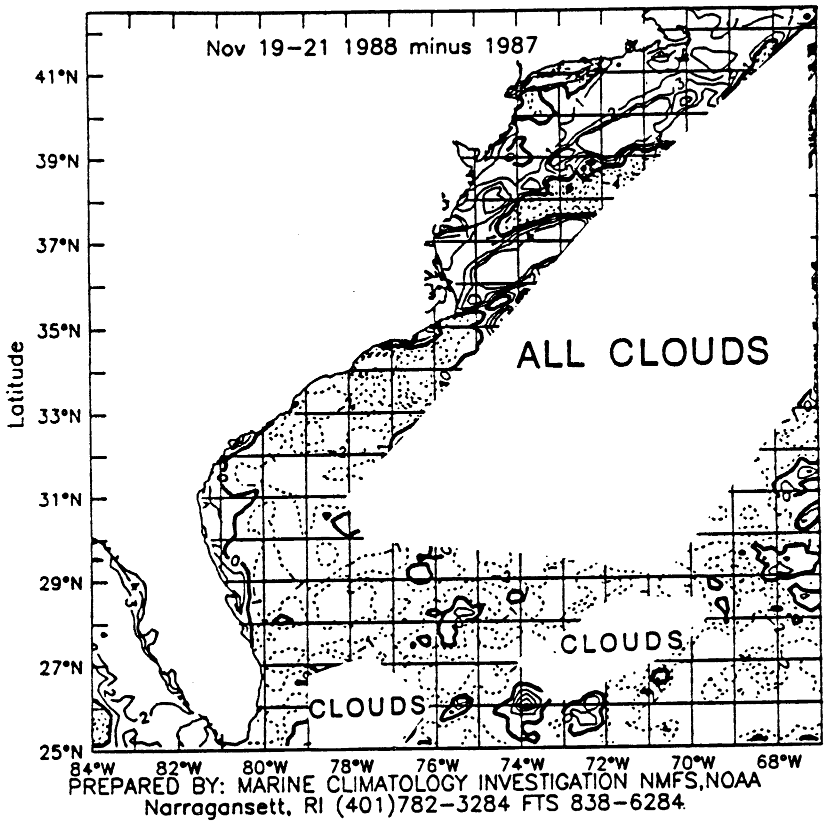

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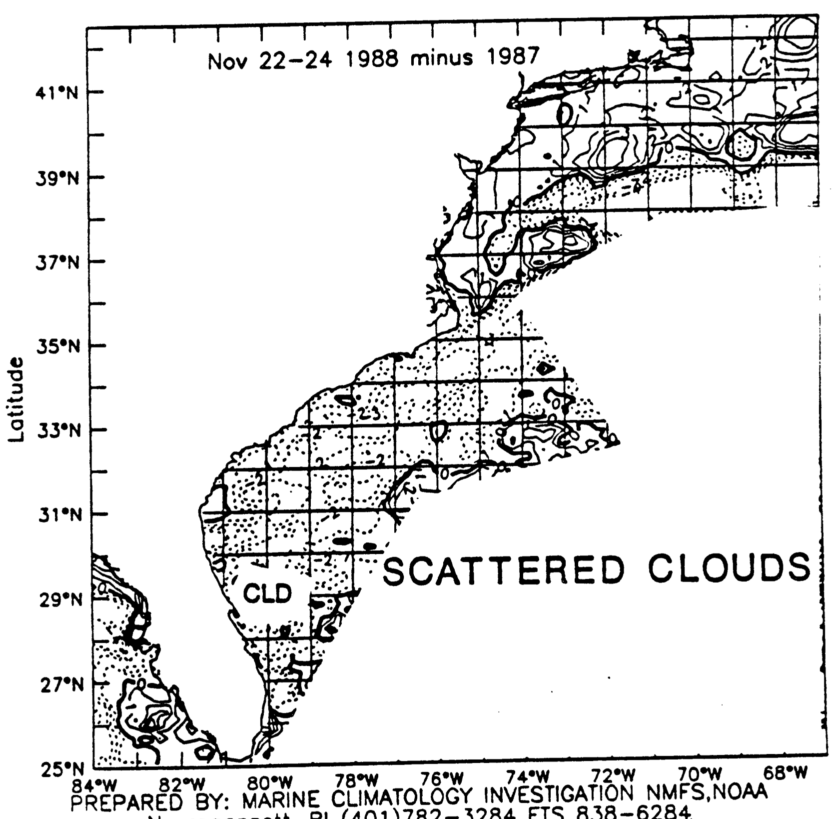

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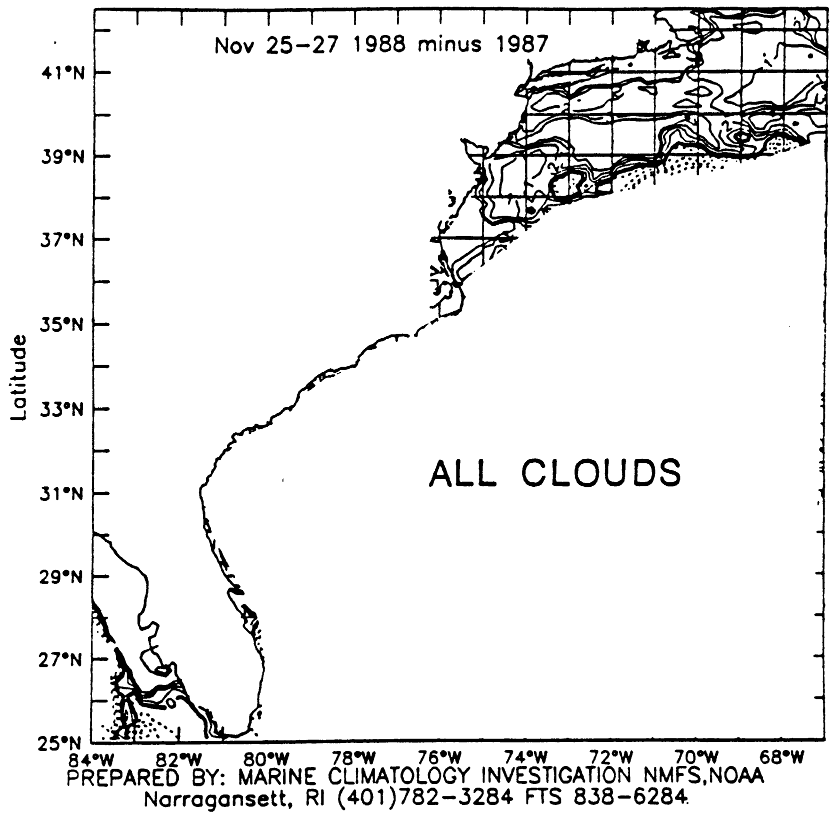

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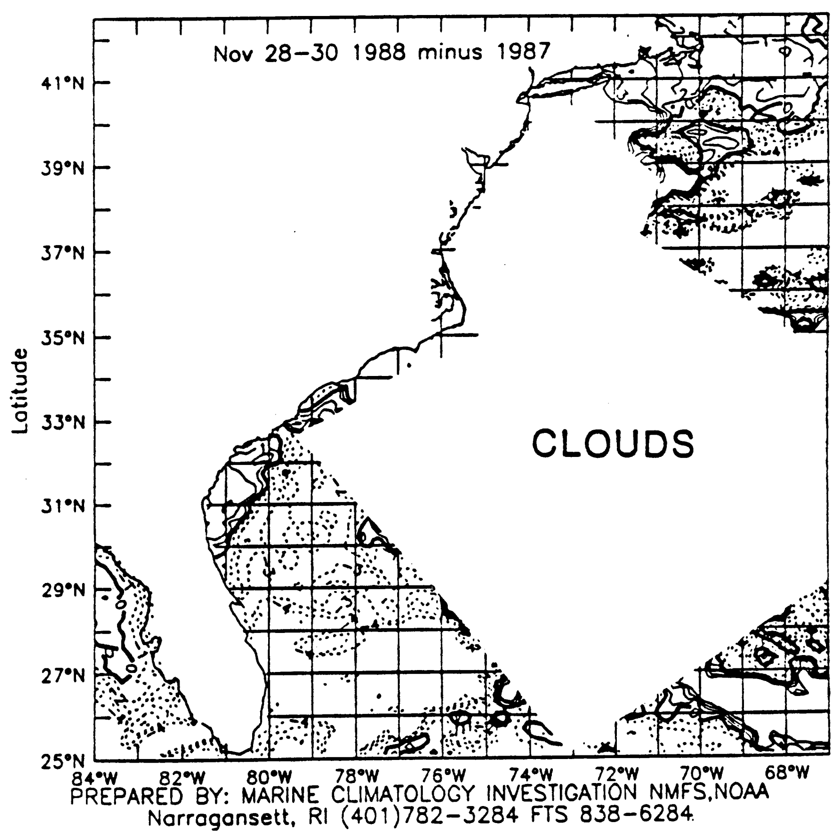

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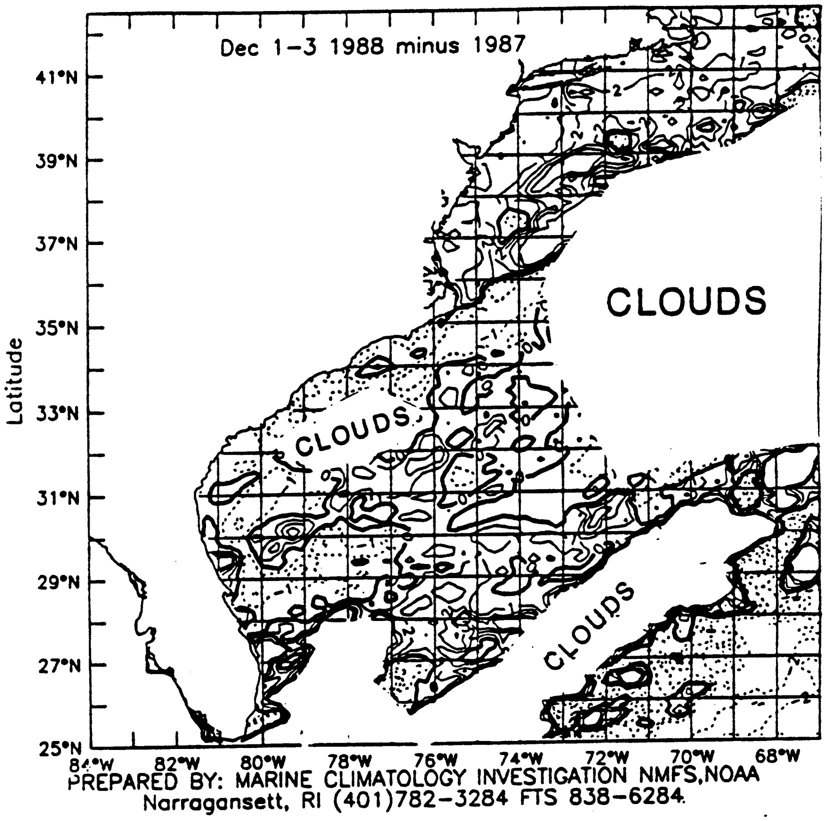

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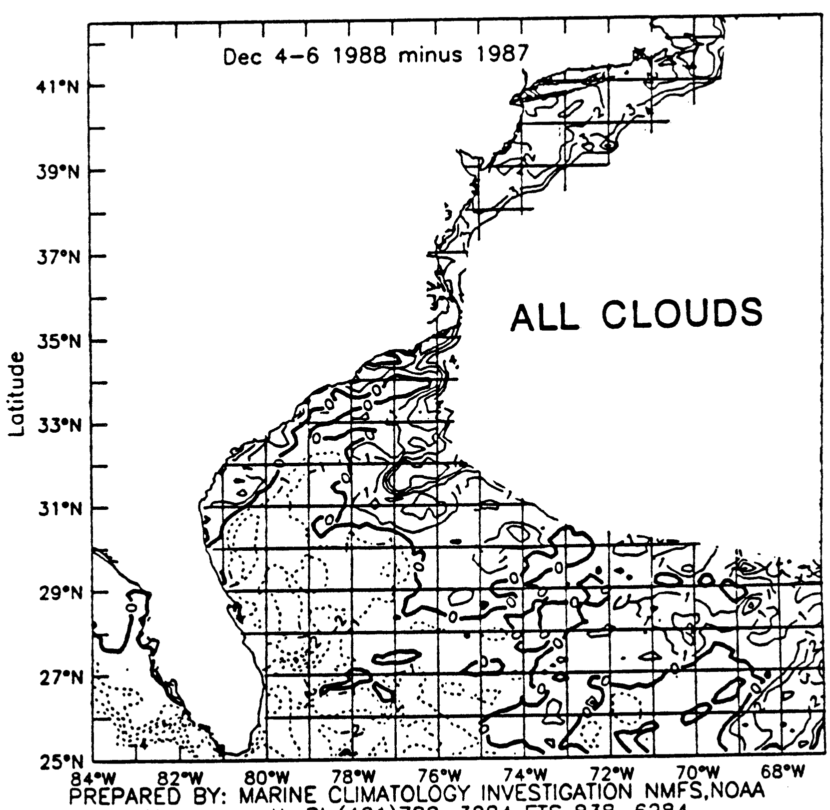
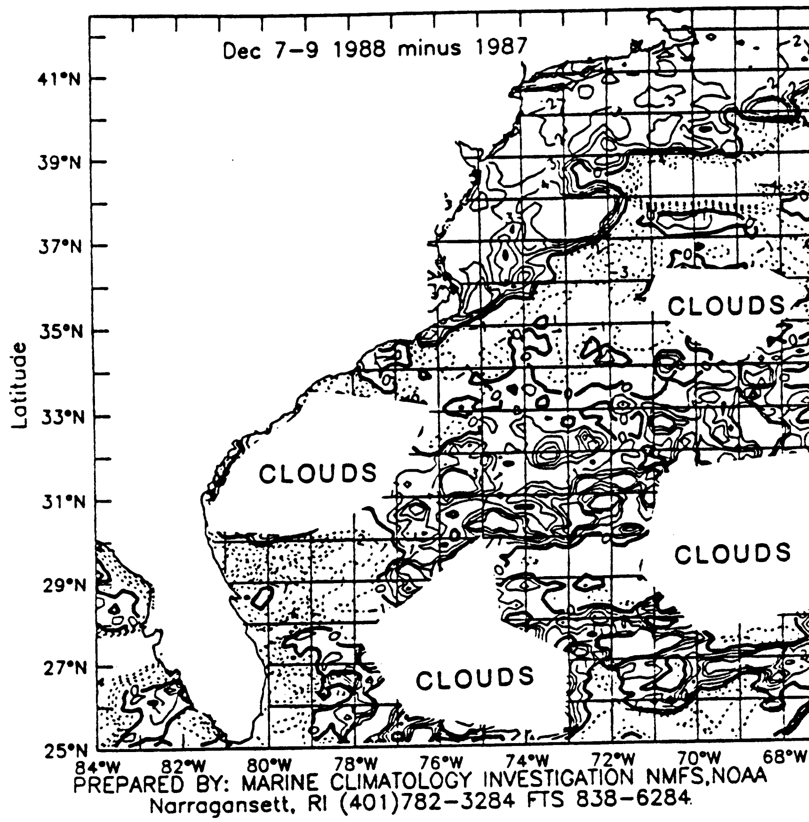


Figure A21. December 7-9, 1988 minus 1987.



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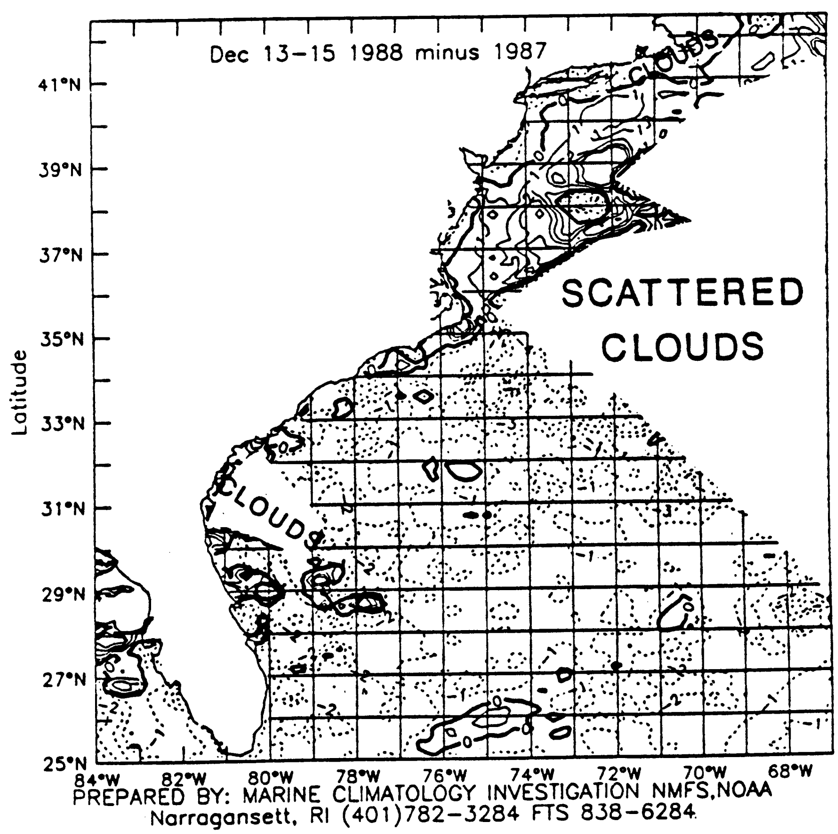

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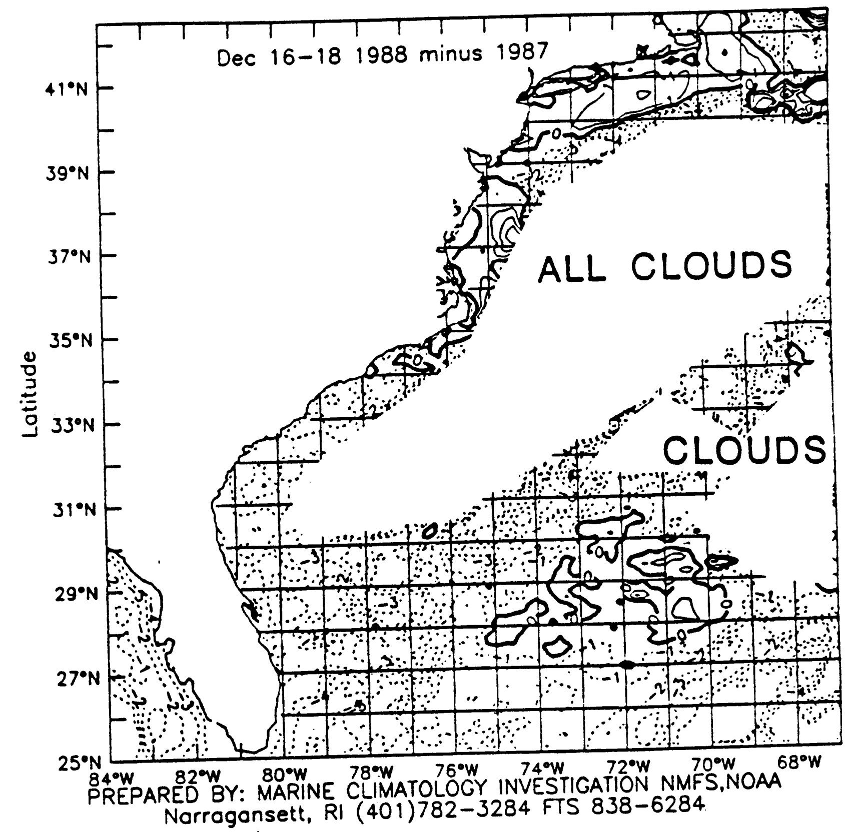

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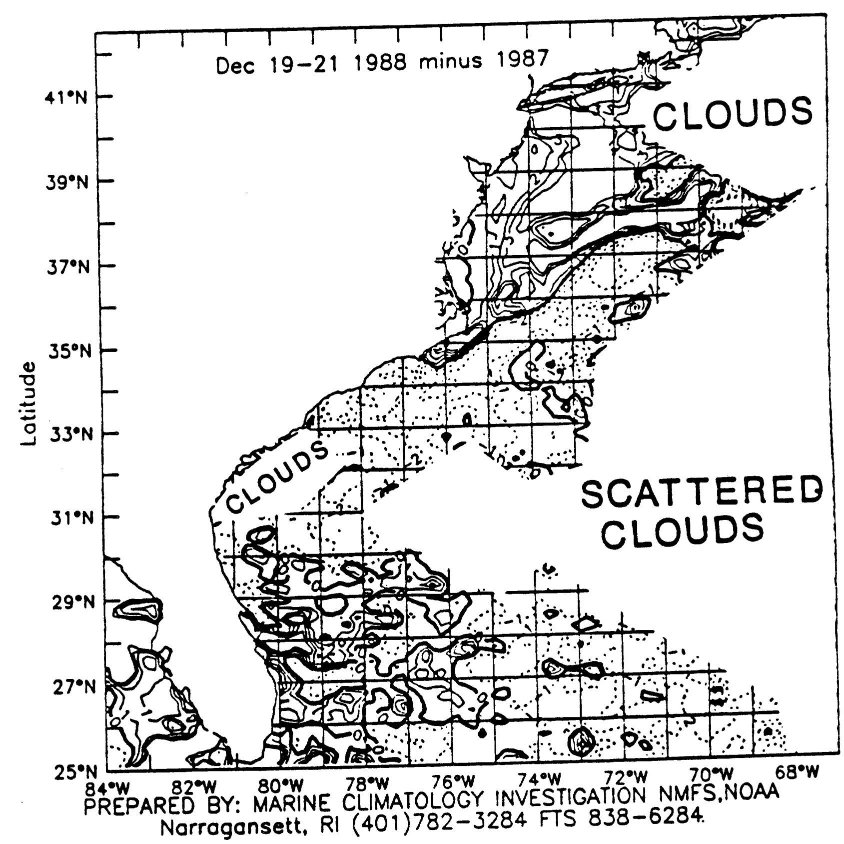
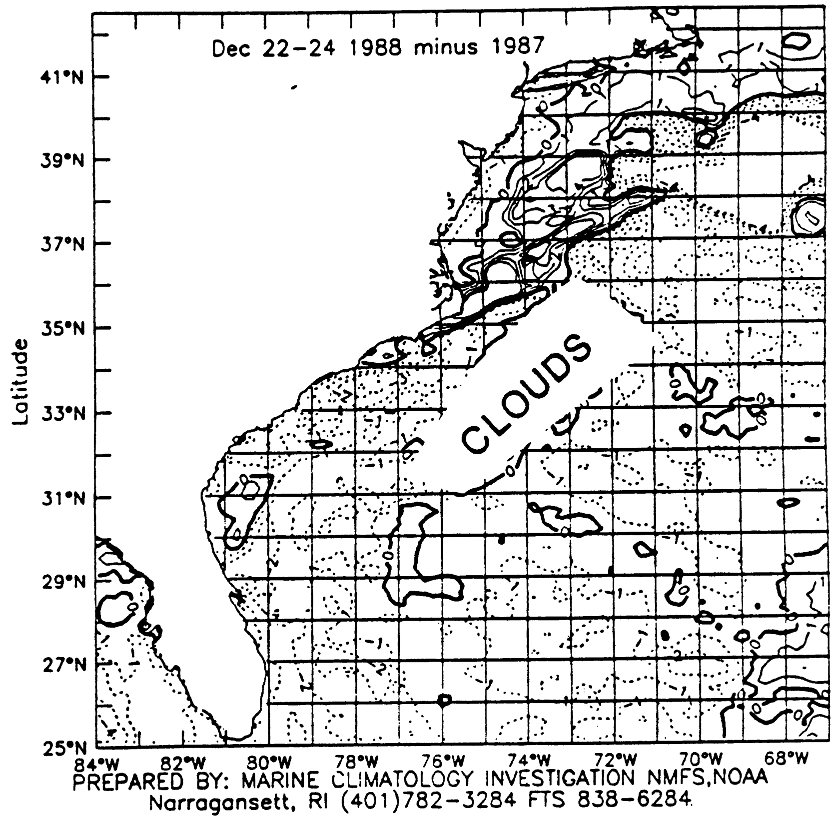


Figure A25. December 22-24, 1988 minus 1987.



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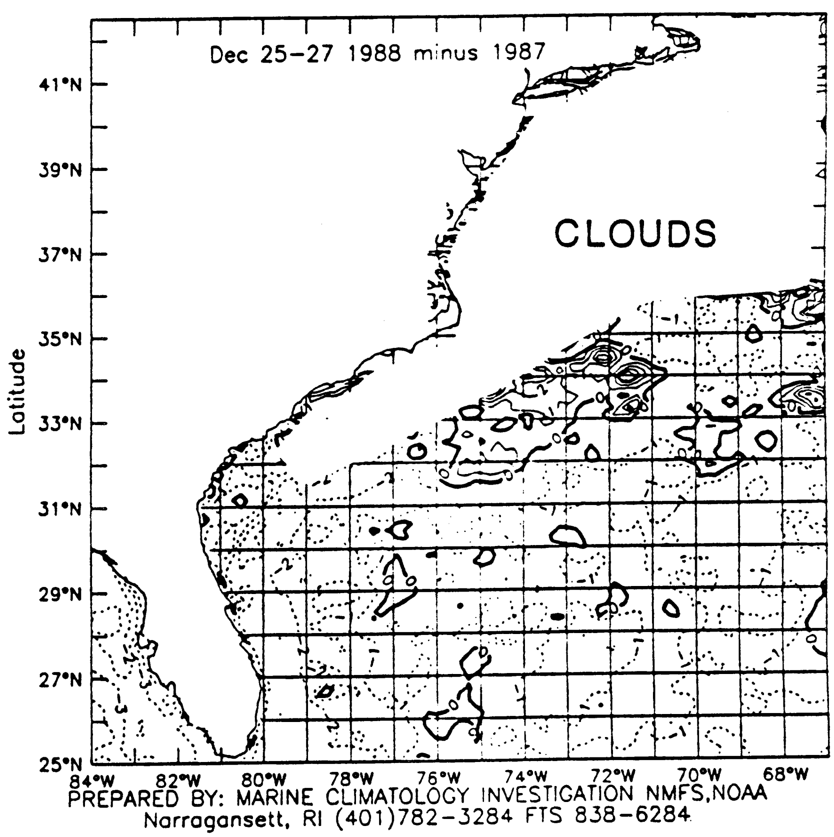


Figure A27. December 28-31, 1988 minus 1987.

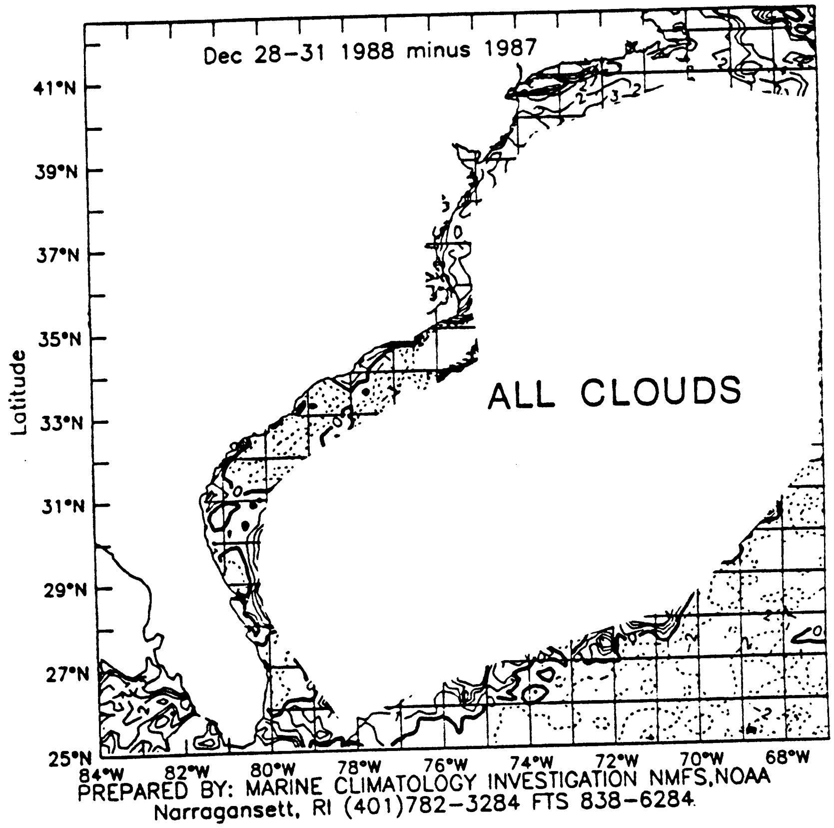


Figure A28. January 4-6, 1989 minus 1988.

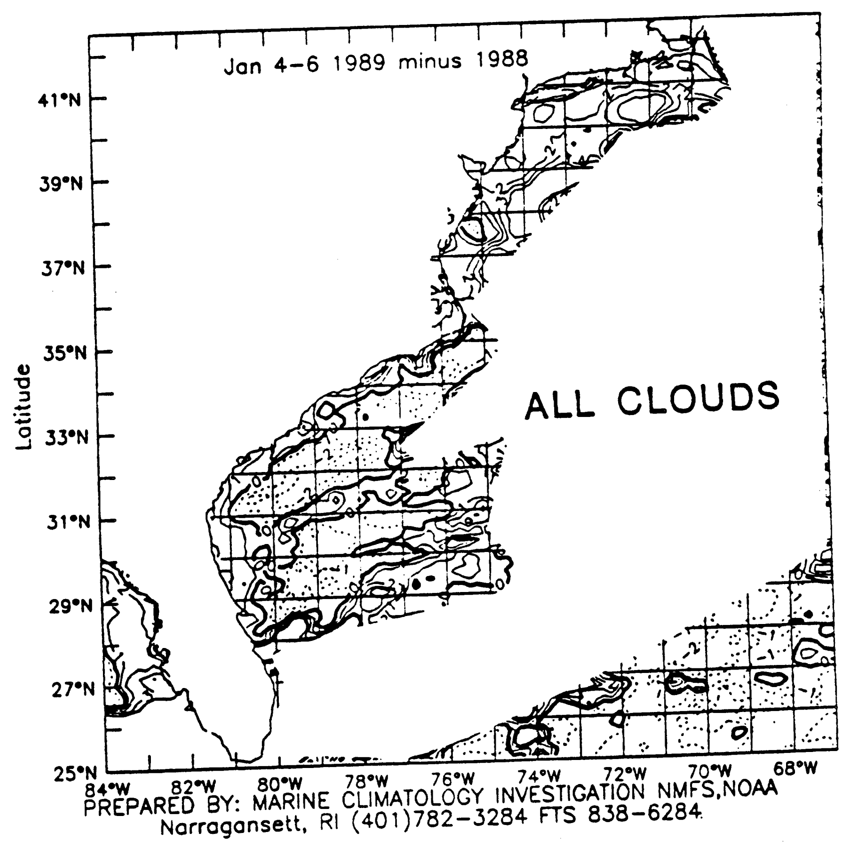
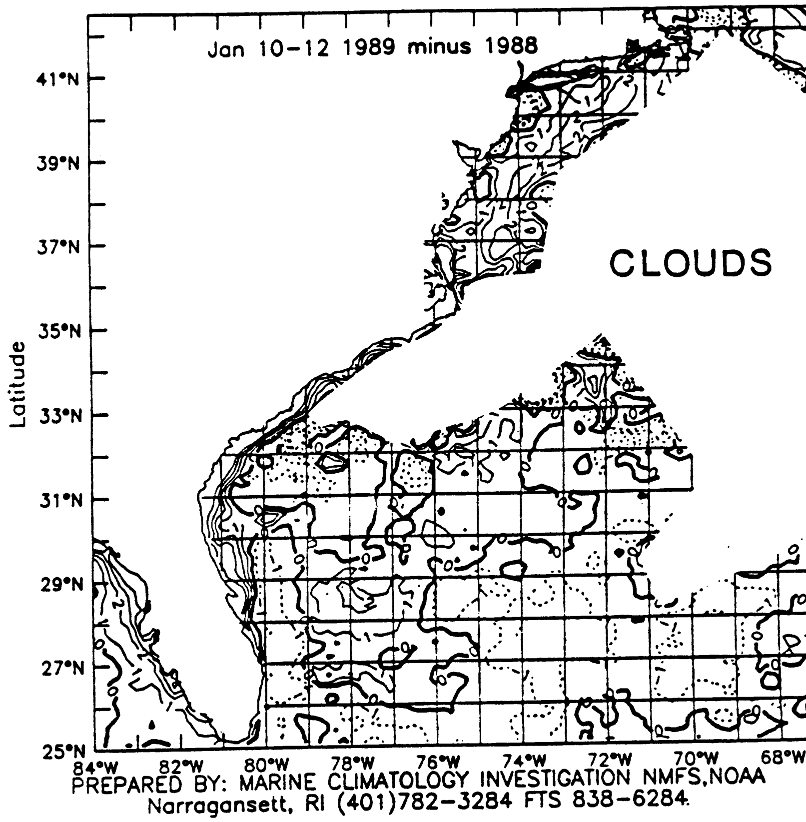


Figure A29. January 10-12, 1989 minus 1988.



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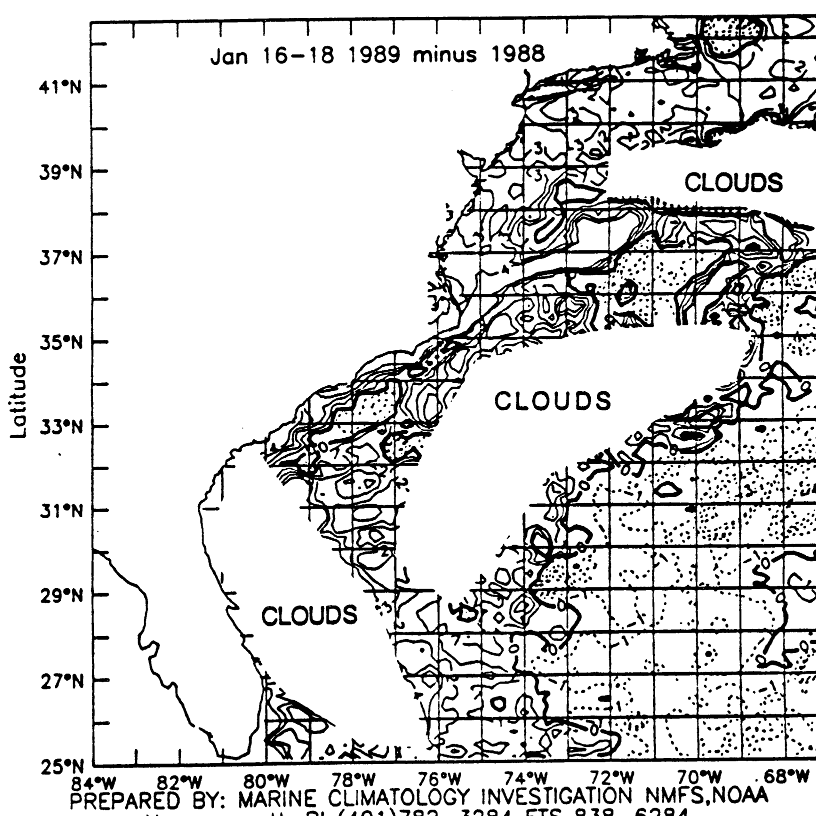
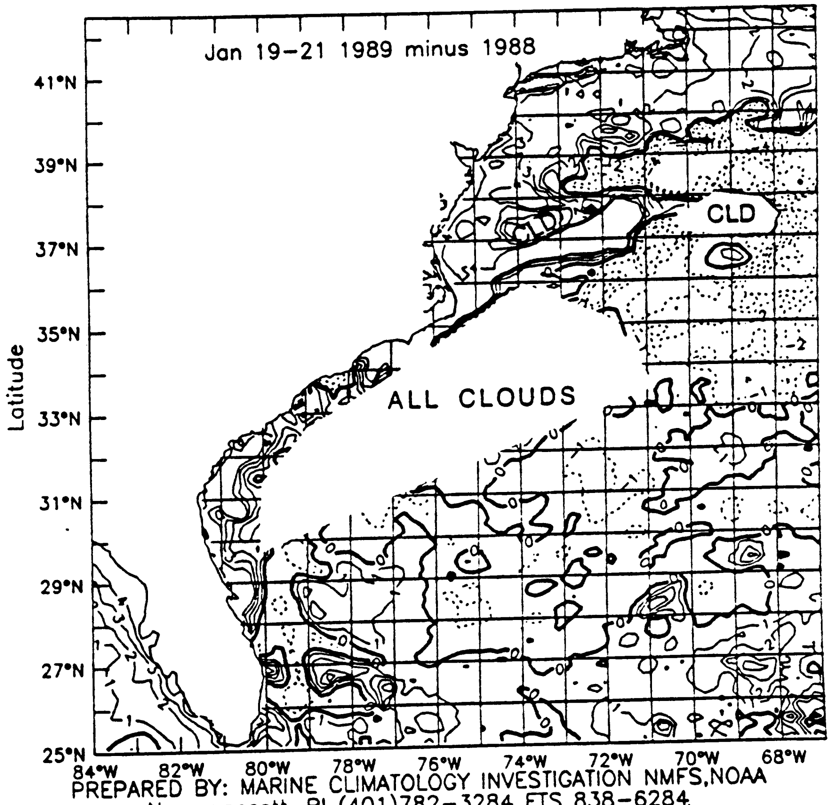


Figure A31. January 19-21, 1989 minus 1988.



Appendix B
Sea Surface Temperature Plots
Derived from Buoy Records

The following plots depict sea surface temperatures as derived from the records of three NOAA data buoys moored off the U.S. East Coast. The data have been smoothed (three day averages) to illustrate the general trend of the SST and eliminate high frequency variation. Gaps in the lines indicate periods of no data recorded by a buoy.

Figure B1. Sea surface temperatures recorded by NOAA buoy 44008 (40.5°N, 69.5° W), 1987-1988.

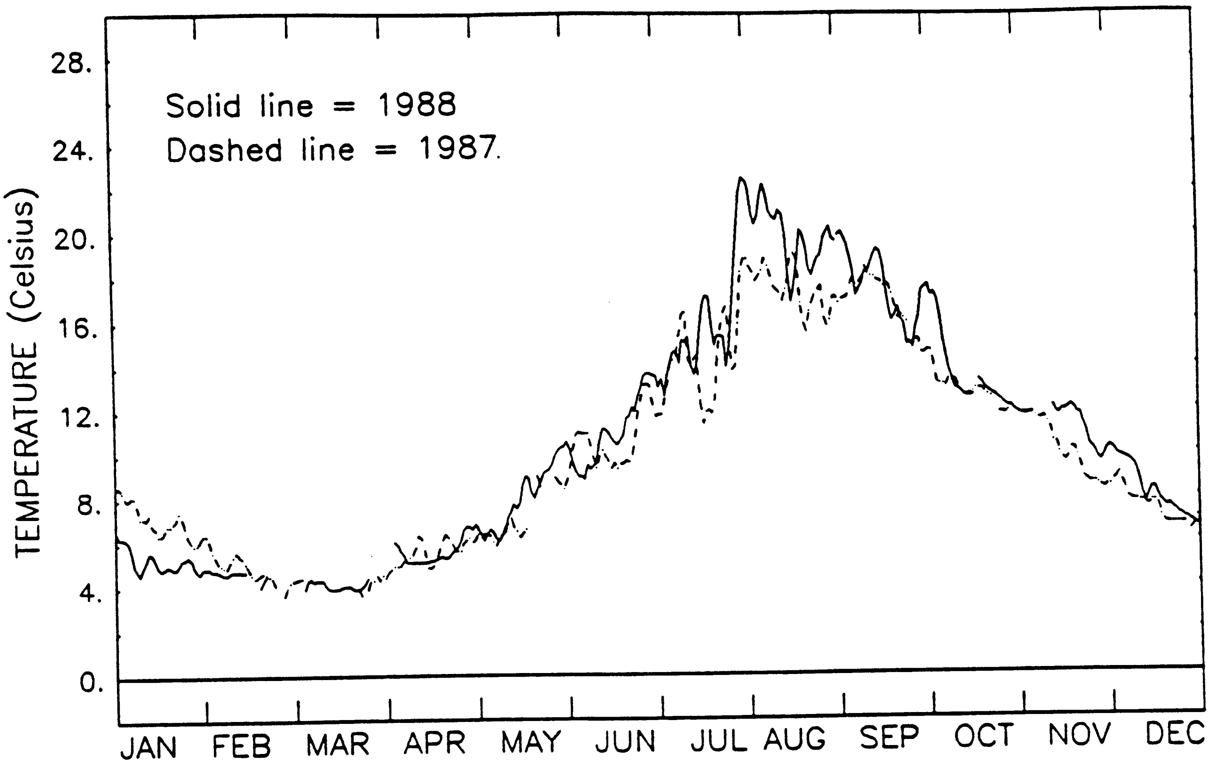


Figure B2. Sea surface temperatures recorded by NOAA buoy 44008 (40.5°N, 69.5° W), 1983-87, 1988.

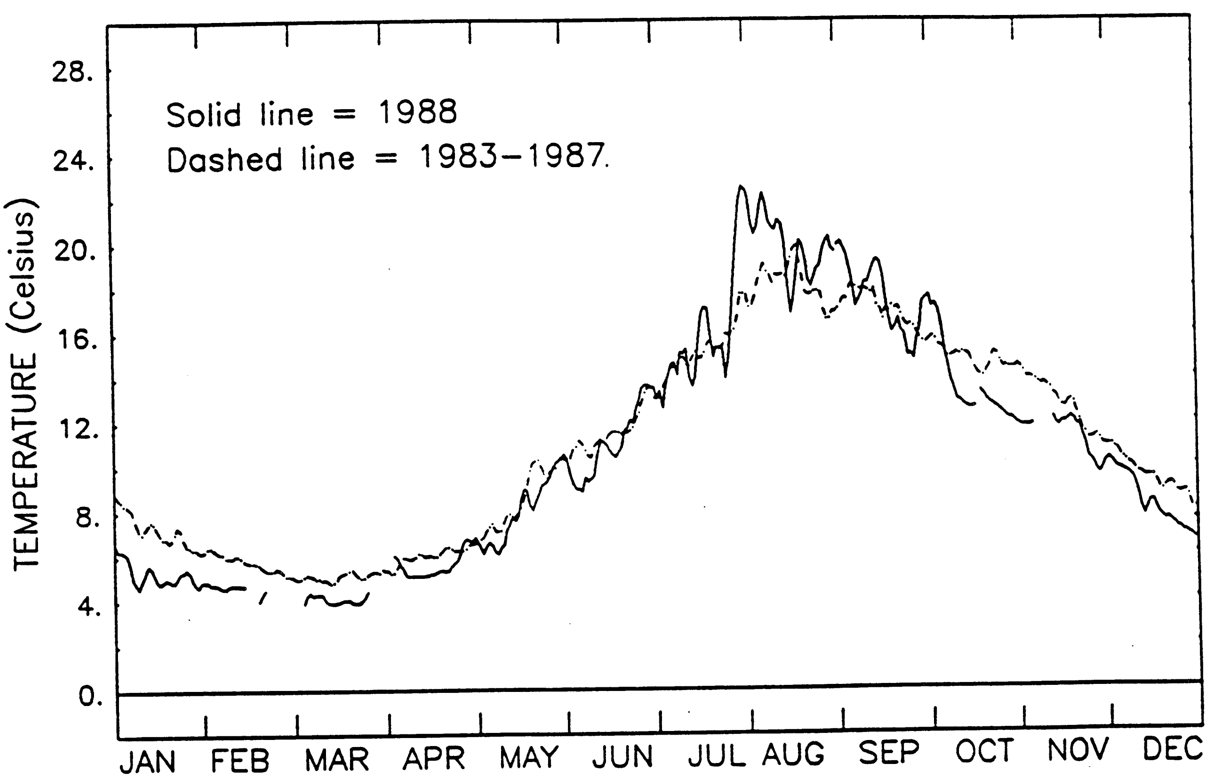


Figure B3. Sea surface temperatures recorded by NOAA buoy 44012 (38.8°N, 74.6° W), 1987-1988; no SST for Jul-Aug, 1988 due to buoy malfunction.

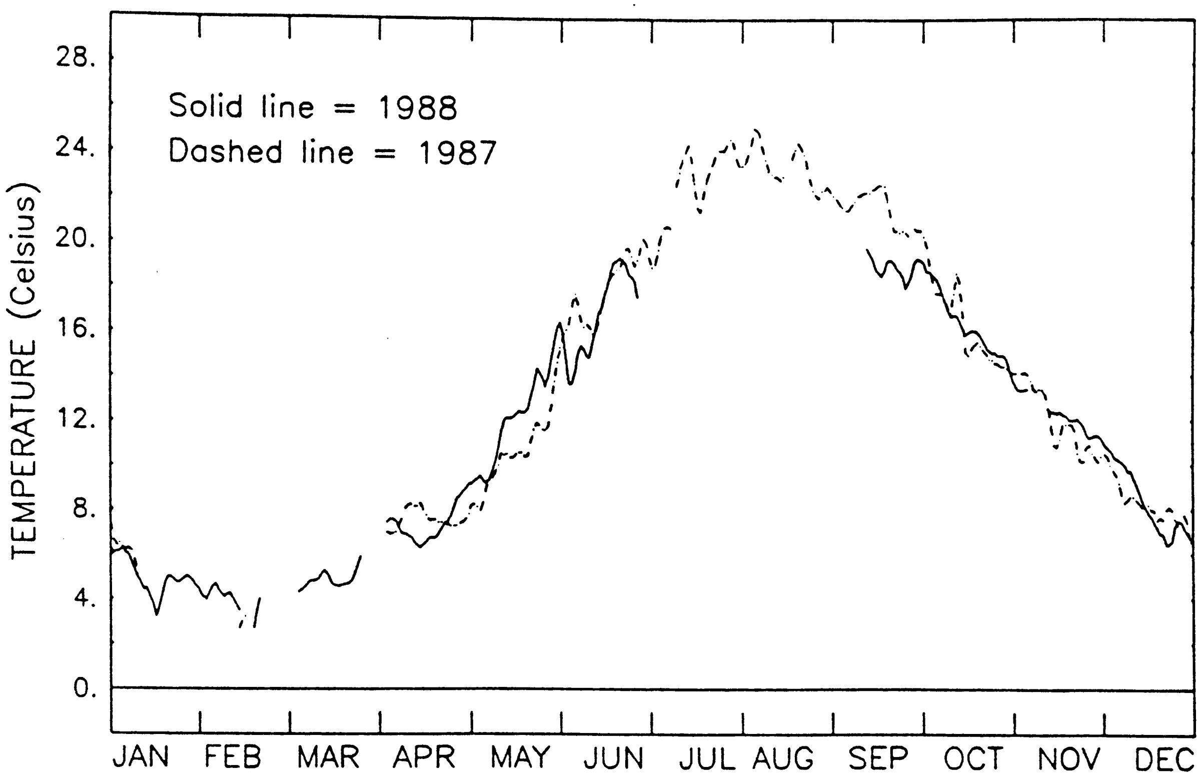


Figure B4. Sea surface temperatures recorded by NOAA buoy 44012 (38.8°N, 74.6° W), 1983-87, 1988; no SST for Jul-Aug, 1988 due to buoy malfunction.

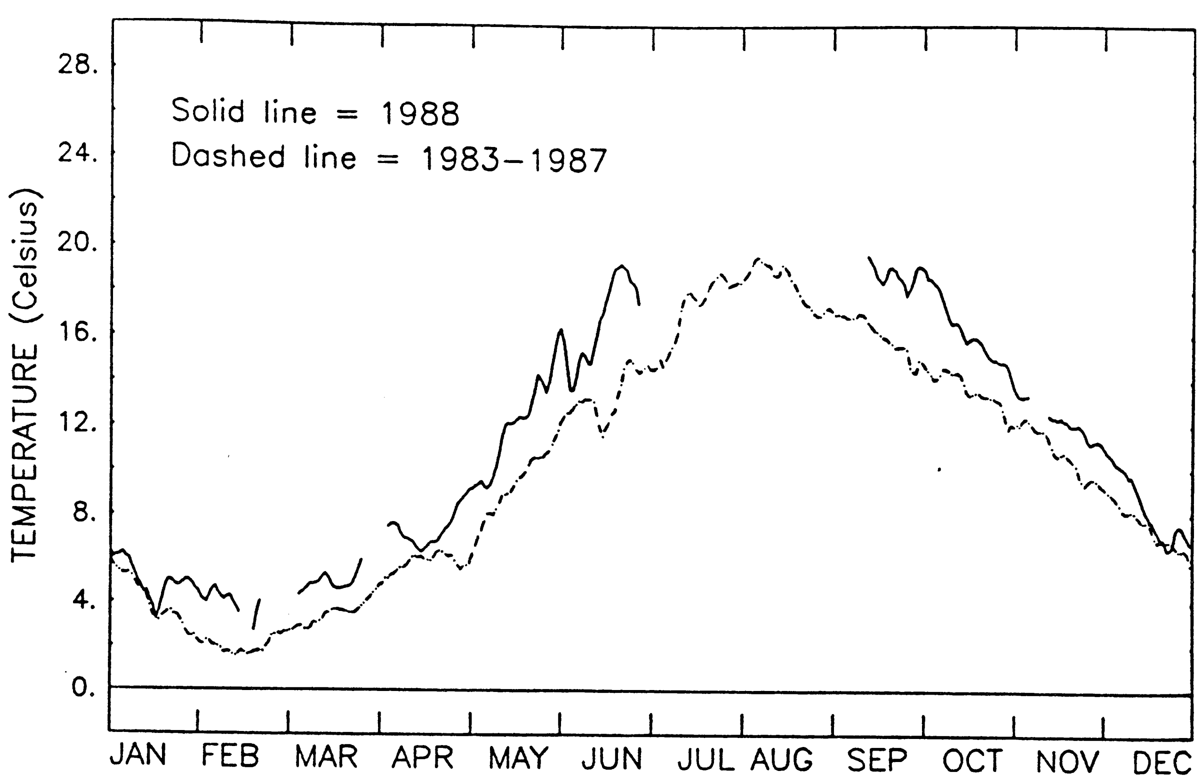


Figure B5. Sea surface temperatures recorded by NOAA buoy at Ambrose Light (40.5°N, 73.8° W), 1987-1988.